Appendix A: Biographical Sketches for Investigators

Kenneth J. Rothman is a Professor of Public Health at Boston University, an Adjunct Professor of Epidemiology at Harvard School of Public Health, and was a founder of ERI in 1980. Dr. Rothman has a doctoral degree in Dental Medicine from the Harvard School of Dental Medicine, a master's degree in Public Health and a doctorate in Epidemiology and Biostatistics from the Harvard School of Public Health. From 1972 to 1984 he was an Assistant and then Associate Professor of Epidemiology at the Harvard School of Public Health. He was a member of the editorial board of the **New England Journal of Medicine** from 1978 to 1990. He also has been an editor of the **American Journal of Epidemiology**, and Assistant Editor of the **American Journal of Public Health**. In 1984-85 he was President of the Society for Epidemiologic Research. Dr. Rothman has written extensively on epidemiologic methodology, and is the author of a widely used epidemiologic textbook, *Modern Epidemiology*, published in 1986 by Little, Brown and Company. He has lectured on epidemiologic methods for many years, and teaches a popular course on the principles of epidemiology in the New England Epidemiology Summer Program. Currently he is Editor of the journal **Epidemiology** and serves as a senior scientific advisor to ERI projects.

Nancy A. Dreyer is President and Chief Executive Officer of Epidemiology Resources Inc. and was a founder of the company. She received her master's and doctoral degrees in Epidemiology from the University of North Carolina at Chapel Hill. For two years she was Director of Epidemiologic Research for Equifax, Inc., where she developed epidemiology as a new program area. Dr. Dreyer started Epidemiology Resources Inc. and the New England Epidemiology Institute in 1980, which has had substantial, steady growth ever since and has earned a reputation for excellence. Dr. Dreyer has been principal investigator for a variety of epidemiologic research projects, including studies relating to occupational, environmental, and pharmaceutical agents, and she serves as an internal reviewer for all projects conducted by ERI. Dr. Dreyer continues as Director of the New England Epidemiology Summer Program, a position she has held since the program's inception in 1980. She also oversees the publications division of ERI, including the journal **Epidemiology**. Outside of ERI, Dr. Dreyer has participated as a task force member on maintaining radiation protection records for the National Council of Radiation Protection and Measurements since 1984. She served as a Consumer Representative to the Committee on Radiopharmaceuticals of the Food and Drug Administration from 1986-1990. Dr. Dreyer serves as a director for two other companies, the Drug Research Group Inc. and Marion Zimmerman Inc., a medical billing company.

Donnie P. Funch joined ERI in 1987 as an Associate Epidemiologist and was promoted to Senior Associate Epidemiologist in 1993. She earned a master's degree in Epidemiology and a doctoral degree in Medical Sociology from the State University of New York (SUNY) at Buffalo. At ERI, Dr. Funch has managed a number of studies. Most recently, she led a study designed to identify patient and/or manufacturing characteristics associated with valve fracture in an effort to identify risk factors that will help determine which patients should have their artificial heart valves explanted. Prior to this, she managed a study of the side effects from long-term drug therapy for rheumatoid arthritis, the development of a registry of immunosuppressive drug protocols used in solid organ transplants, a case-control study of puerperal seizures and strokes, and a study of the health effects of environmental exposure to electric and magnetic fields and direct current. Before joining ERI, Dr. Funch was Assistant Professor in the Department of Social and Preventive Medicine at SUNY from 1984 to 1986. She received a Junior Faculty Research Award in 1984 from the American Cancer Society and a Research Competition Award from SUNY in 1985. She has written or co-authored more than 25 original articles on pharmacoepidemiology, behavioral and socio-environmental factors affecting the early diagnosis, therapy and outcome of disease.

Appendix B: Cohort Data Security Protocol

Version dated May 18, 1995

ERI has devised a custom security protocol expressly to deal with data received from cellular telephone companies. These security procedures are designed to eliminate the risk of fraudulent use of two key data elements [electronic serial number (ESN) and mobile identification number (MIN)], while permitting their use for record linkage in epidemiologic surveillance. Here we outline the main aspects of the security protocol. These security procedures will be reviewed at intervals by external security consultants to maintain the most thorough security measures possible for these key elements and to adapt this protocol to handle any other issues that may be raised as the study proceeds.

Downloading Data from Cellular Carriers

Our research data from cellular carriers contain identifying information for cellular customers and information on cellular telephone use. The identifying information includes the ESN and MIN, as well as customer name, Social Security number, address and account number. The ESN and MIN are essential elements which together form a unique identifier representing a specific cellular telephone/user combination. In addition, we need ESN to link with manufacturing data to identify telephone type. We also need the area code (NPA) and exchange (NXX), which are derived from the MIN, to assign the home cell site density of the user in order to estimate average power output of the telephone during use. We will encourage cellular carriers to encrypt the last four digits of the telephone number before sending data to us, to maintain security during transit. The encryption scheme must remain consistent over time; we need a stable system to enable us to link identical telephone numbers over a period of years.

Companies may provide customer data on a single or multiple tape(s). Upon receipt of these data at ERI, project personnel download the tape(s) according to the format accompanying the tape(s). If no data layout was received with the tape(s) or the received data layout does not work, we will attempt to download the tape(s) with an unformatted option. If this is successful, we will verify the correct format with the carrier. Otherwise, the tape(s) will be returned to the carrier to be rewritten. Once a tape is successfully written to disk, the magnetic tape will either be securely erased or returned to the carrier, via an agreed upon shipper, if they have requested us to do so.

ERI Data Encryption and Security Procedures

As soon as a tape is successfully downloaded to disk, we remove ESN and MIN from all data files kept on-site and replace them with a single unique identifier.

Briefly, the MIN and ESN in each record are encrypted using a custom key so as to be unrecognizable. The original forms of the MIN and ESN are then deleted. Two different ERI staff members or their alternates must work together to run the encryption programs. The encryption and unencryption programs are kept only in a compiled form that is impossible to list or to modify without access to the source code, which is kept off-site in a locked vault. The encryption and unencryption programs will only be brought back to site in their compiled versions. The programs cannot be run without a "key" file that is also kept off-site in a secure location and is accessible only to the Principal Investigator. When it is time to encrypt a new file, the key file will be brought on-site and accessed by the compiled encryption program; the key file will then be removed from the site.

After encryption, the unique identifier is created to replace both the ESN and MIN in the original data. The encrypted versions of the ESN and MIN are removed from the data file and stored in two separate files along with the new linking unique identifier. These two files will be stored in separate locations off-site. The variables remaining in the stripped data file include: unique linking identifier, name, address, Social Security number, account number, and information on cellular telephone use. ERI will retain the area code (NPA) and exchange (NXX) as two separate geographic indicators until the information required to calculate cell site density is provided by the carrier. Once the carrier provides this information, these two geographic variables will also be deleted from the stripped data file.

EXHIBIT B

Overall Mortality of Cellular Telephone Customers

Kenneth J. Rothman, Jeanne E. Loughlin, Donna P. Funch, and Nancy A. Dreyer

Unlike mobile cellular telephones, in which the antenna is not part of the handset, a portable cellular telephone exposes the user's head to radio frequency energy transmitted from the antenna. This exposure has prompted concerns about potential biological effects, including brain cancer. As a first step in a record-based mortality surveillance of cellular telephone customers, we report on overall mortality of a cohort of more than 250,000 portable and mobile telephone customers during 1994. We found age-specific rates to be similar for users of the two types of telephones. For customers with accounts at least 3 years old, the ratio of mortality rates in 1994 for portable telephone users, compared with mobile telephone users, was 0.86 (90% confidence interval = 0.47–1.53). (Epidemiology 1996;7:303–305)

Keywords: cellular telephones, mortality, electromagnetic energy, radio frequency energy.

Case reports of brain cancer among cellular telephone users have prompted investigations into the possibility that exposure to cellular radio frequency energy may have adverse health effects.[1] For cellular telephone users, the main determinant of exposure is the type of cellular telephone. Handheld portable models have the antenna in the hand piece, in close proximity to the head. In contrast, the antenna for mobile or transportable bag phones is located separately from the hand piece, and the radio frequency energy dissipates before reaching the body.[2] To evaluate the possible effect of using cellular telephones on risk of death, we have begun mortality surveillance of a cohort of telephone users. We here report preliminary findings regarding overall mortality rates of customers of a large cellular telephone carrier.

Methods

We obtained data from all cellular telephone markets covered by one of the larger U.S. cellular telephone carriers. The markets, which cover the metropolitan areas of Boston, Chicago, Dallas, and Washington DC, are served by four different data processing systems. We requested representatives of each data processing system to provide a computer file of all noncorporate, single-phone customers who had active accounts as of January 1, 1994, and who had at least two complete billing cycles with the company during November and December 1993. We excluded accounts that were clearly corporations, because it is difficult to link a corporate telephone to a specific user from the data that were available to us. We also excluded accounts that listed multiple telephones, for which we are less likely to be able to identify the actual user of each telephone. We received a total of 770,390 records from the four markets.

We requested information about each customer regarding name, address, city, state, zip code, date of birth, mobile telephone number, account number, electronic serial number (ESN) (a unique serial number embedded into each cellular telephone at the time of manufacture), Social Security number (SSN), type of telephone, and start of service date. Some of these data items were not available from the cellular carrier: date of birth, gender, and type of cellular telephone were never recorded; SSN was available for 83% of the 770,390 customers in the cohort. We contracted with a credit bureau to provide SSN, date of birth, and gender for the cohort. The credit bureau was able to find SSN for 65% of subjects, date of birth or year of birth for 63%, and gender for 78% of the records searched.

Although type of telephone (mobile *vs* portable) was not available from the billing data, we were able to assign telephone type for a large subset of customers based on the ESN. The first few characters of the ESN identify the manufacturer of the telephone. With the help of Motorola Corporation, the largest manufacturer of cellular telephones in the United States, we were able to identify the telephone type for 99% of the customers in the study who used Motorola telephones.

After receiving the raw data, we eliminated all records that had a SSN that was also listed for another record, which indicated a household with more than one telephone. This procedure reduced the file to 603,843 records with uniquely occurring SSNs. To these records, we added the data obtained from the credit bureau, and

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TABLE 1. Number of 1994 Deaths and Persons at Risk by Age, Gender, and Telephone Type

Age (Years)	Men			Women		
	Mobile	Portable	Unknown	Mobile	Portable	Unknown
20–24	0/1,023	2/1,904	2/3,069	1/1,075	0/1,263	2/2,376
25–29	2/2,985	2/3,782	7/8,406	0/2,143	1/1,923	1/5,117
30–34	1/4,879	1/5,071	8/13,801	0/2,857	0/2,238	4/6,746
35–39	3/5,723	4/5,283	15/15,293	2/3,156	0/2,384	3/7,687
40–44	1/5,540	4/4,801	16/15,011	1/3,312	0/2,480	0/7,881
45–49	8/5,442	5/4,018	28/13,773	0/3,038	0/2,091	3/6,995
50–54	9/4,135	8/2,826	21/9,850	3/2,119	6/1,497	5/4,955
55–59	13/2,770	5/1,837	21/6,661	3/1,413	2/936	4/3,237
60–64	16/2,096	8/1,317	43/4,633	5/906	1/650	8/2,124
65–69	26/1,563	17/920	55/3,210	3/708	1/450	7/1,571
70–74	30/946	10/497	44/1,932	4/454	1/255	5/1,003
75–79	9/445	6/236	28/860	3/207	1/100	7/508
80–84	7/148	5/89	18/325	1/83	0/38	0/143
≥85	3/59	2/36	3/115	0/20	0/10	0/58
Total	128/37,754	79/32,617	309/96,939	26/21,491	13/16,315	49/50,401

then we eliminated records that did not have identical SSNs and name fields from the two data sources. By limiting our selection to those customers who had identical information from two different sources, we restricted the cohort to a subset that had some validation of the information used for linkage. A total of 316,084 records remained. We eliminated an additional 75 records that had account names suggestive of a corporate account. Finally, we excluded records that lacked a year of birth or for which gender information was unconfirmed, leaving 256,284 records for linkage.

At this early stage in our surveillance, we do not yet have access to data on specific causes of death; here, we report on overall mortality during calendar year 1994. The only death file available now with data on 1994 deaths is the Social Security Administration's Death Master File, the latest release of which has deaths recorded through the first quarter of 1995. We searched this file for matches with our cohort. We considered a death record to be matched to a cohort member if the SSN matched exactly, the first five characters of the last name matched, the first letter of the first name matched, and the year of birth matched within 3 years.

Results

We found 408 deaths among cohort members that occurred before the start of 1994; we excluded these individuals from our analyses. The final cohort therefore comprised 255,868 individuals. Of these, 65% were male. The median age among the men was 42 years, and for women, 41 years. Median age was similar for users of different types of cellular telephone (mobile, 43 years; portable, 40 years; unknown telephone type, 42 years). Twenty-three per cent of the customers in the final cohort had a Motorola mobile telephone; 19% of the final cohort had a Motorola portable telephone; telephone type was unknown for the remaining 58%.

We identified 604 deaths among cohort members that occurred during 1994. In Table 1, we present the distribution of the entire cohort and those who died during 1994 by gender, age, and type of telephone used. Figure 1 gives age-specific mortality rates for portable and mobile telephone users; for this analysis, we standardized the rates among men and women to the gender distribution among portable telephone users, which is two-thirds male. The mortality curves for portable and mobile telephone users showed little difference.

We also compared mortality rates between portable telephone users and mobile telephone users who had been listed as continuing customers with the same cellular provider for at least 2 years, and, in a separate analysis, at least 3 years. For these analyses, we had fewer subjects (≥2 years of continuous use, 148,723 subjects; ≥3 years of continuous use, 63,309 subjects), but the results bear more closely on the overall effect on mortality of continuing use of portable cellular telephones. We partitioned the data into 28 strata, 14 categories of age and two of gender, and obtained the maximum likelihood estimate of the mortality rate in portable telephone users *vs* mobile telephone users.[3,4] The results of the stratified analysis are given in Table 2. They show

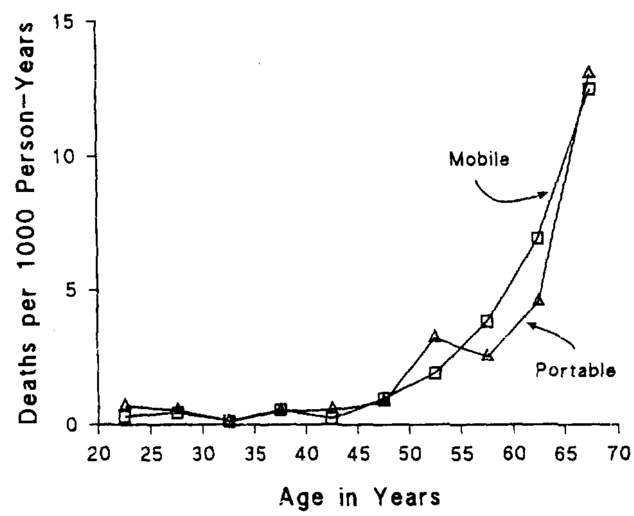

FIGURE 1. Age-specific mortality rates among users of mobile and portable cellular telephones.

TABLE 2. Mortality Rate Ratio Estimates for Portable *vs* Mobile Cellular Telephone Users of at Least 2 or 3 Years' Duration, Controlling for Age and Gender

Length of Service (Years)	Mortality Rate Ratio	90% Confidence Interval
2	0.93	0.67–1.29
3	0.86	0.47–1.53

a slightly lower rate of mortality for portable cellular telephone users. There was substantial confounding by age and gender in these analyses; the corresponding crude point estimates of the mortality rate ratio were, for those with at least 2 years of use, 0.74 rather than the unconfounded 0.93, and for 3 years of use, 0.64 rather than 0.86.

Discussion

The overall mortality rates of portable and mobile cellular telephone users are similar. The mortality rates reported here are much lower than corresponding rates for the general population, especially in the older age categories. In part, the low mortality presumably reflects the higher socioeconomic status of cellular telephone account holders. There may be additional selection factors explaining the low rates, since people who are not mobile may have little need for a cellular telephone. The Death Master File also misses some deaths and thus results in an unknown degree of underascertainment. We expect that underascertainment should be equal, however, for the users of different types of cellular telephones and therefore would not bias our comparison. Low mortality rates for cellular telephone users in general should also affect users of different types of cellular telephones nearly equally. Missing information, which led to the discarding of a substantial proportion of the original cohort, likewise should be unrelated to type of cellular telephone used.

These preliminary findings have two important limitations. First, they do not directly address the issue of the relation between cellular telephone use and brain cancer, which comprises only a small proportion of deaths. Second, the time between the exposure to radio frequency energy from portable cellular telephones and the death endpoints that we measured was comparatively short, and our study therefore addresses only short-term effects. The findings do provide evidence that there is no large short-term effect on overall mortality, and they provide a starting point for future surveillance efforts.

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EXHIBIT C

Cellular Telephones and Health

The use of cellular telephones, first marketed in 1983, has increased exponentially during this past decade. A recent federal report[1] estimates that over 16 million Americans now use cellular telephones, and in 1994 the telecommunications industry estimated that over 60 million people will be using portable cellular communication devices by the year 2000. All devices that transmit radio frequency (RF) signals, such as radio broadcast towers and cellular telephones, emit radio frequency radiation. Cellular telephones are really mobile radios that operate at frequencies between 824 and 850 MHz (mobile units) and between 869 and 894 MHz (base stations). These frequencies are just above the UHF-TV portion and just below the microwave portion of the electromagnetic spectrum. Thus, although cellular is a new and rapidly growing communications medium, we have decades of experience with the underlying radio technology.

No research has been completed on long-term human exposure to low levels of radiation specifically from portable cellular telephones. Public concerns regarding the safety of cellular telephones heightened considerably in 1993 owing to publicity surrounding an anecdotal report in the news media. These concerns emphasized the need to assess the human health effects associated with use of cellular telephones. After this report was broadcast, a number of efforts were initiated by government and industry groups.

Epidemiologic research to date has found no persuasive evidence that low-power microwave radio communications signals adversely affect human disease. Similarly, the now fairly extensive research on the health effects of extremely-low-frequency (ELF) electric and magnetic fields has provided no conclusive evidence of an adverse effect on human health. It is estimated that population exposures resulting from base stations or cellular towers would be equivalent to that estimated from power transmission lines.

Current available research findings are insufficient to conclude that there are no long-term adverse health effects—either from handheld wireless communication devices or from cellular towers. This lack of evidence neither establishes the absence of an effect nor provides grounds for presuming that a hazard exists. It is this crucial gap that a large, new epidemiologic study of cellular telephone users seeks to address.

Two early reports in this issue,[2,3] and an accompanying review of exposure assessment issues related to cellular telephones,[4] represent the first phase of findings from this research. The work is one component of a large, multifaceted research agenda funded by the telecommunications industry via a mechanism to ensure independence from industry influence.[5] The epidemiologic component, reported for the first time here, is the establishment of a record-based mortality surveillance system for cellular telephone users. The challenges looming in this study are daunting, and the investigators are meeting the challenges head on. They have identified a way to enumerate an extremely large cohort of cellular telephone users and classified them in a way that provides a useful natural contrast: they compare mortality among users of portable cellular telephones, in which the transmitting antenna is in the handset, with that among users of mobile cellular telephones, in which the antenna is built into the automobile and not near the user's head. As a preliminary, they have surveyed a sample of cellular telephone users to identify characteristics that may influence exposure, and they have devised an unbiased way to estimate radio frequency exposure from billing records.

The report on the mortality experience of this cohort of cellular telephone users is a first look. It addresses only all-cause mortality for a short interval after exposure. Nevertheless, it provides a hint of what will be possible as the data accumulate over longer periods of time. Most importantly, these early results offer some reassurance, specifically that a large increase in mortality is not associated with radio frequency exposures over the short term.

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